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ELECTRICAL, DECENTRALIZED BRAKING SYSTEM IN A VEHICLE

Background of the Invention

The present invention relates to an electrical, decentralized braking system in a vehicle, and in particular to an electrical, decentralized brake-by-wire system for a four-wheeled motor vehicle.

In brake-by-wire braking systems, which as a rule are not provided with a mechanical, hydraulic, or pneumatic backup system, particular emphasis must be placed on availability, i.e. a braking function, even in case of error. Brake-by-wire systems having a centralized brake pedal module are known for example from the laid open print DE 198 26 131 A1, the VDI report no. 1641 (2001), "Error-tolerant Components for Drive-by-wire Systems," by R. Isermann, and the publication "Error-tolerant Pedal Unit for An Electromechanical Braking System," by Stefan Stölzl, published in the year 2000 by VDI-Verlag, ISBN 3-18-342612-9.

A main priority in systems having such a central module is the reliable acquisition of the actuation of the brake pedal (the parking brake will not be considered in the present context), as well as the distribution of the information concerning the brake actuation to decentralized intelligent wheel brake modules. The reliability of such a system is ensured on the one hand by a diversified and multiply redundant sensor design (see brake pedals S1 to S3 according to Figure 3) and on the other hand by a redundant processor and communication design (see first and second communication bus 14, 14' between central brake pedal module 15 and the four brake modules 10, each controlling a wheel 13), with the boundary condition of a multi-circuit on-board network.

In addition, the communication device or communication system is required to have a deterministic characteristic, from which the use of time-controlled communication systems, such as for example FlexRay, TTCAN, or TTP, results immediately. In this context, the brake pedal module and the communication system must have a fail-operational characteristic. In order to meet the requirement of a fail-operational characteristic in the case of simple errors, the brake pedal module must have at least three redundant processors as well as three redundant, diversified if necessary, sensors for the service brake. At least two redundant communication channels are required for the communication system.

Laid open print DE 199 37 156 A1 discloses an electromechanical braking system having a decentralized acquisition of the brake pedal actuation. This can be referred to as a distributed, decentralized pedal module functionality.

Within this electromechanical braking system design, shown with reference to Figure 4, four diversified sensors S1 to S4 are provided for the acquisition of the actuation of a brake actuation device (not shown), respectively determining for example the pedal path and the pedal angle. Each of the sensors S1 to S4 is connected to exactly one wheel module 10 having a device 11 for determining a braking demand. Wheel modules communicate with one another via a system bus 14 and exchange the required sensor information or data, and, parallel thereto, calculate functional algorithms, agreeing on a protocol in such a way that in each wheel module 10 the same data, i.e. sensor actual values and sensor/function status, are present, and identical decisions can be made.

Consequently, in this way a symmetrical, decentralized system architecture is provided in which the required fail-operational approach of the central pedal module according to Figure 3 is here (i.e. according to Figure 4) reproduced via the redundancy of intelligent wheel modules 10, 11. However,

if a common mode error now occurs in communication system 14, for example due to a mechanical wiring harness breakage in the area of the wheel housing caused by a foreign influence, e.g. during off-road operation, this will lead unavoidably to a total loss of communication, in particular given a bus topology of communication system 14. In such a case, each wheel module 10 will then have access only to one sensor value, which however will no longer be able to be sufficiently plausibilized. This can result in differing braking forces being applied to the different wheels 13 of the vehicle, resulting in a yawing moment, and thus in pulling to one side of the vehicle. Already in the case of a single error, this represents a significant loss of safety, independent of the backup management strategy.

Advantages of the Invention

In comparison with the known solution approach, the electrical, decentralized braking system having the features of Claim 1 has the advantage that, even after a common mode error or after the occurrence of two simple errors, at least a part of the wheel modules can plausibilize sensor values through comparison with at least one additional sensor value, thus ensuring safety against a second error.

In this way, increased reliability and availability of the service brake is ensured in case of error, which is required in pure brake-by-wire systems without mechanical/hydraulic backup systems for a safe trip to a workshop.

The underlying idea of the present invention is essentially that at least a part of the wheel modules can plausibilize sensor values through comparison with at least one additional sensor value even after a common mode error or after the occurrence of two simple errors.

In other words, an electrical, decentralized braking system is provided with: at least four sensors for acquiring the

actuation of a brake actuating device; one brake module per brakable wheel of the vehicle for acquiring sensor data and controlling a braking device of a corresponding wheel; at least one first communication device with which all braking modules are connected to one another for the exchange of data; and an electrical connection device by which each sensor is connected at least to one brake module, the braking system having at least one additional communication device for receiving and/or exchanging data between at least two wheel modules of opposite sides of the vehicle.

The subclaims contain advantageous developments and improvements of the braking system indicated in Claim 1.

According to a preferred development, the second communication device is constructed identically to the first communication device, and each sensor is connected to a second wheel module of the opposite side of the vehicle. In this way, the necessary and reliable plausibilization of the sensor values can take place via the additional duplex system of the two local sensors, even when a common mode error has occurred in the communication system, i.e., both communication devices or communication lines fail.

According to a further preferred development, a front wheel module of one side of the vehicle is connected to a rear wheel module of the other side of the vehicle via a second communication device, and a front wheel module of the other side of the vehicle is connected to a rear wheel module of the one side of the vehicle via a third communication device for exchanging data. This has the advantage that after the occurrence of two independent simple errors affecting the communication devices, or one common mode error (e.g. due to mechanical foreign influence in the area of the wheel housing), a communication, and thus a plausibilization, of the sensor values is still possible between at least two wheel braking modules on opposite sides of the vehicle.

According to a further preferred development, more than four sensors, allocated to the wheel modules in pairs, are provided for acquiring the actuation of the brake actuating device. This is advantageous because it provides an additional increase in redundancy at a low expense.

According to a further preferred development, the communication devices are formed by serial bus systems. This advantageously permits the use of known communication platforms.

Drawing

Exemplary embodiments of the present invention are shown in the drawings, and are explained in more detail in the following description.

Fig. 1 shows a schematic block diagram of a braking system for the explanation of a first specific embodiment of the present invention;

Fig. 2 shows a schematic block diagram of a braking system for the explanation of a second specific embodiment of the present invention;

Fig. 3 shows a schematic block diagram of a known braking system; and

Fig. 4 shows a schematic block diagram of an additional known braking system.

Description of the Exemplary Embodiments

In the Figures, identical reference characters designate identical or functionally identical components.

Figure 1 schematically shows a block diagram of an electrical braking system that has four sensors S1, S2, S3, and S4. The four sensors S1 to S4 determine an actuation of a brake actuating device (not shown), such as for example a brake

pedal, that is actuated by a user of the vehicle. The four sensors S1 to S4 all detect the same parameters, such as for example a pedal path and a pedal angle. Intelligent wheel braking modules 10, or wheel modules that are provided with a device 11 for determining the brake demand or a desired braking (brake demand distribution), are each connected with one of the four sensors S1 to S4 via an electrical line 12. Four wheels 13 are connected via wheel modules 10 or wheel braking devices (not shown) connected therewith.

Moreover, wheel braking modules 10 are all connected to one another via a communication device 14 that permits an exchange of data between intelligence wheel braking modules 10. According to the specific embodiment in Figure 1, in addition a second and third communication device 14' and 14'' are provided, such that each of these communication devices 14', 14'' connects a wheel module 10 of one side of the vehicle R, L with a wheel braking module 10 of the other side of the vehicle L, R in order to exchange data, and preferably e.g. the front right wheel RV is connected to the rear left wheel LH and conversely, so that a diagonally opposite connecting is ensured. First, second, and third communication devices 14, 14', and 14'' are preferably a serial bus system.

Communication device 14 enables communication among all four wheel braking modules 10, and preferably with additional control devices, such as for example ABS or VDM control modules. Via this communication channel 14, the pedal sensor values of sensors S1 to S4 of the four wheel braking modules 10 are exchanged. In addition, via the two braking circuit data buses 14' and 14'', the pedal sensor values of the two associated wheel braking modules 10VL, HR; VR, HL are mutually exchanged. This creates the possibility of (limited) monitoring, via the two braking circuit data buses 14', 14'', of the data sent via first communication channel 14.

After the occurrence of two independent simple errors affecting communication devices 14, 14', 14'', or the occurrence of a common mode error, e.g. due to mechanical foreign influence in the area of the wheel housing resulting in breakage of the communication bus connections to the corresponding wheel, one communication device 14' or 14'' is thus still intact, so that a plausibilization of the pedal sensor values of sensors S1 to S4 is still possible between at least two wheel braking modules 10 VR, HL or VL, HR. A system of this sort therefore has the possibility of switching off wheel braking modules 10 that can no longer communicate via a communication system 14, 14', 14'', in order to avoid undesirable or unmatched braking forces, and thus a possible pulling of the brakes of the vehicle. This results in increased safety, both in the case of a simple error and also in the case of a double simple error, or of a common mode error.

Figure 2 shows a schematic block diagram of an electrical braking system according to a second specific embodiment of the present invention. The specific embodiment according to Figure 2 is distinguished from the specific embodiment explained with reference to Figure 1 essentially by the modified communication or connection structure between wheel braking modules 10. As in the first specific embodiment, the braking system according to the second specific embodiment also has a communication device 14, preferably a serial data bus, that connects all wheel modules 10 having brakable wheels 13 to one another. In addition, a second communication line 14', redundant to the first communication system 14, is provided that likewise connects all wheel modules 10 to one another. Besides electrical connections 12 between sensors S1 to S4 for acquiring the actuation of a brake actuating device (not shown) and wheel modules 10 according to Figure 1, in Figure 2 additional electrical connections 12' are provided. Electrical connections 12' run from a respective sensor, e.g.

S2, to a wheel module 10 that is situated axially next to the wheel module 10 that is connected to the connection 12 of the sensor, e.g. S2. That is, each of sensors S1 to S4 is electrically connected, via connection 12 and connection 12', to two wheel braking modules 10 situated on one axle.

The decentralized system design for acquiring a user brake demand according to the second specific embodiment thus has exactly two of the four sensors S1 to S4 connected to each of the four wheel modules. Alternatively, solutions are also conceivable in which more than four physical pedal sensors S1, S2, ..., are allocated in pairs to the four wheel modules 10. The advantage of the proposed second specific embodiment is grounded in the fact that even after the occurrence of two independent simple errors or the occurrence of a common mode error in communication system 14, 14'', wheel modules 10 are indeed no longer able to communicate with one another, but a necessary and reliable plausibilization of the pedal sensor values of sensors S1 to S4 can nonetheless take place via the additional duplex system of the two local sensors S1 to S4. In this way, it is possible to safely brake wheel modules 10 that can no longer communicate with one another via a communication system 14, 14'. This results in increased safety with respect to the failure of the communication system, both in the case in which two simple errors occur and in the case of a common mode error.

Although the present invention has been explained above on the basis of two preferred exemplary embodiments, it is not limited to these, but rather can be modified in a multiplicity of ways.

Although it has been described for vehicles having two axles, the present invention can also be correspondingly carried over to multi-axle vehicles, such as for example three-axle trucks. In addition, it is likewise conceivable to realize connections 12, 12' between sensors S1 to S4 so as to be not only

monodirectional (as is indicated by the arrows in the drawings) but rather, in particular for the second specific embodiment, so as to enable bidirectional communication, via a corresponding sensor, between the two wheel modules 10 connected to the sensor. Under this precondition, it would also be possible to realize a diagonal cross-connection of wheel modules 10 via connecting devices 12, 12' between wheel modules 10, in contrast to the described connection of wheel modules 10 of one axle.